Stability and currents sharing in a conduction cooled racetrack coil wound of YBCO coated conductor tape – FEM modeling

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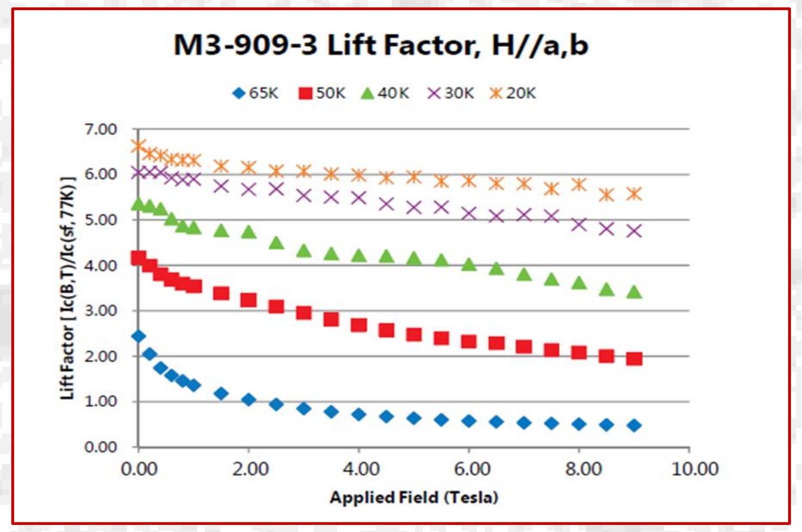
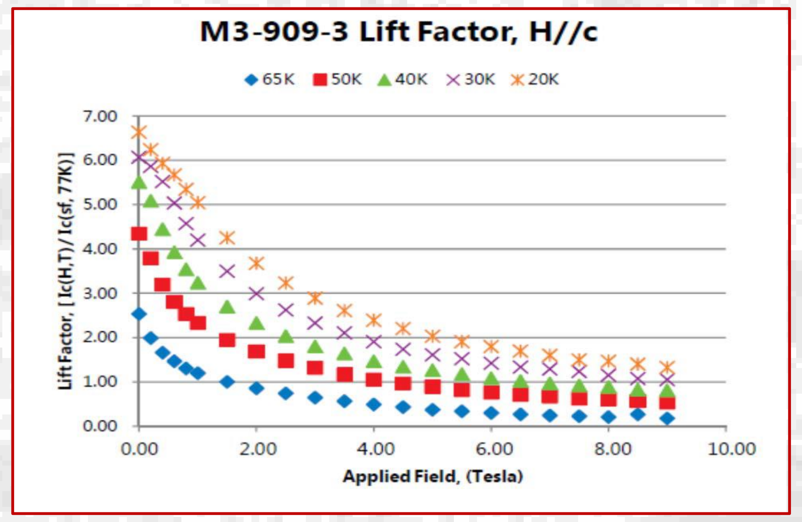
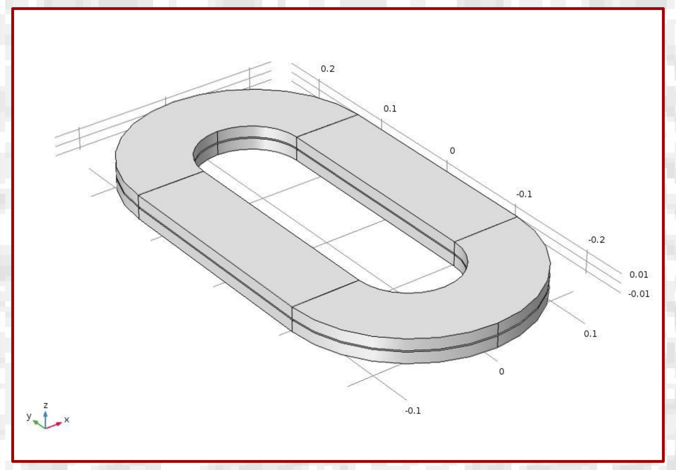
Abstract

We present a Finite Element Method (FEM) analysis of stability and current sharing in a conduction cooled race track coil at 20 K. The coil was assumed to be wound using YBCO coated conductor tape either non-insulated or insulated by a kapton tape. An anisotropic continuum model of the winding for thermal propagation, with input parameters taken from experiments, was developed and adopted in computations. Both coils – with non-insulated as well as kapton insulated tape – have nearly the same critical current. The coil with non insulated tape needs more YBCO tape but can operate at lower current. As a consequence of this the non-insulated coil has a higher operational temperature margin. The coil wound using the non-insulated tape also shows a higher degree of electromagnetic stability because of possible current sharing among the turns within the winding. Stress–strain modeling showed that due to a strong anisotropy of J_c in YBCO film, the critical current of the coils is not limited by mechanical stresses, but by the radial magnetic field component in the winding, i.e. by the field component parallel to c-axis of the YBCO film. Using a power supply in the constant current mode the non insulated tape shows a pronounced current sharing while the insulated tape shows a high degree of power concentrated around the defect region (the so called "hot spot") with power loss density more than three orders of magnitude higher than the power loss density in coil wound using the non-insulated YBCO tape. Magnet length = 0.5 m, magnet width = 0.25 m, magnet thickness = 0.025 m.



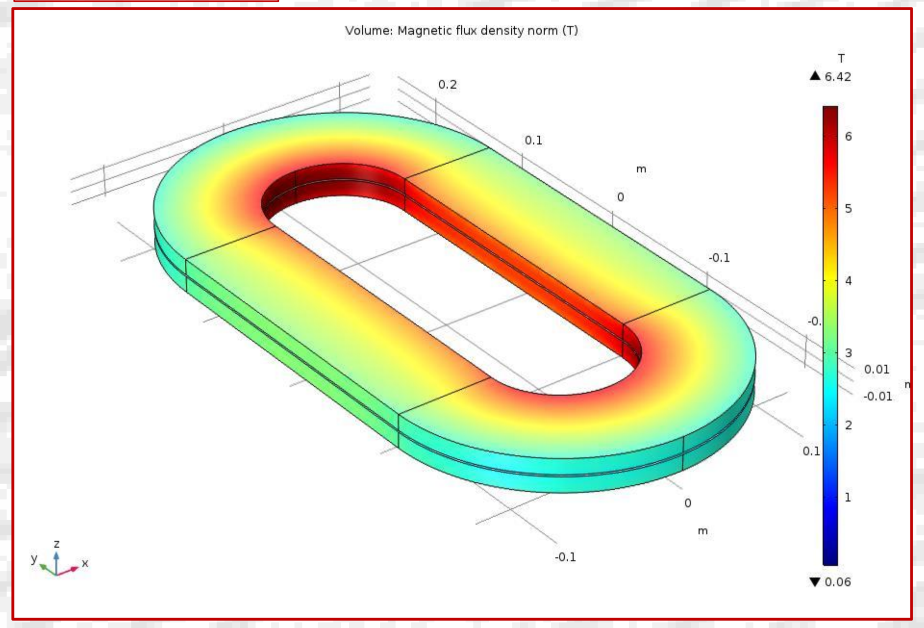




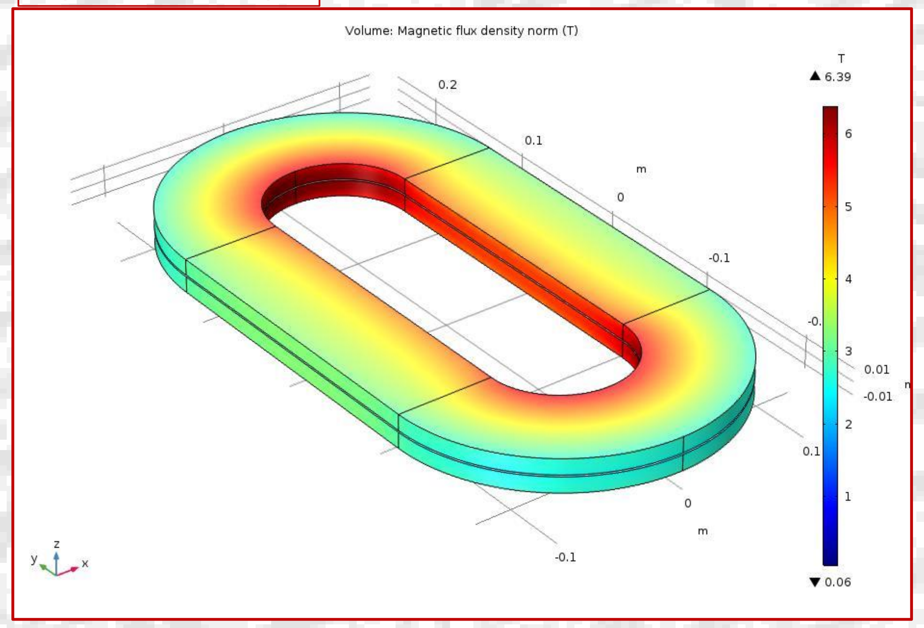
We considered the SuperPower 2G HTS tape with surround 40 μm thickCu stabilizer (critical tensile stress of > 550 MPa at 77K, tape width 12 mm, tape thickness 0.1 mm, critical bend diameter 11 mm both in tension as well in compression, nominal critical current I_c = 300 A at 77 K in self-field). In the modeling of the magnet we found out the current per turn which gave a field of 3 T in the middle of the magnet bore. Then we determined the maximum field in the magnet winding parallel to ab planes as well as parallel to c-axis of the YBCO film. From these magnetic field values we determined the corresponding critical currents at 20 K using the lift factors published by Superpower company. The lower values of those critical currents were considered to be the critical currents of the magnets.

Electromagnetic modeling

Non insulated tape

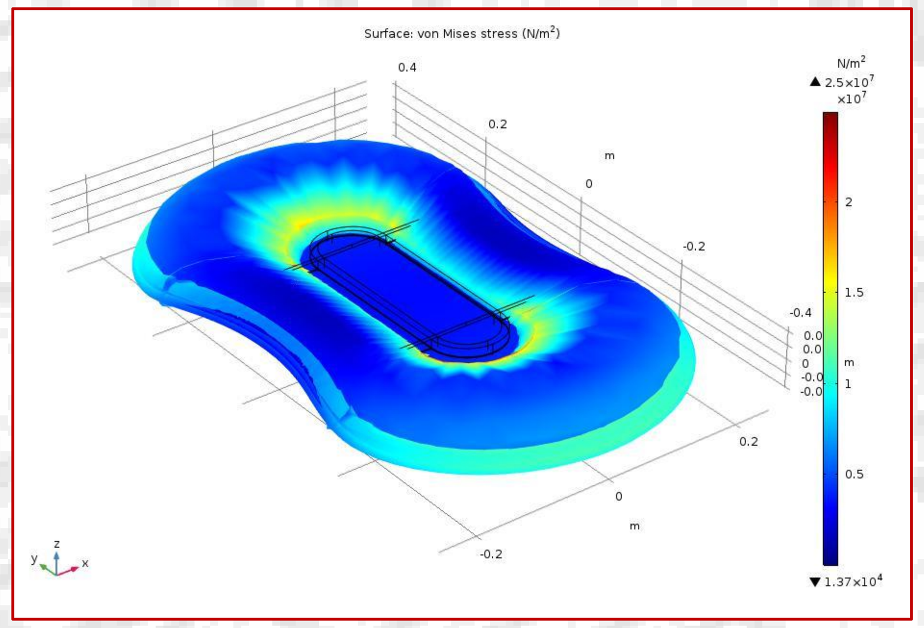


Kapton insulated tape

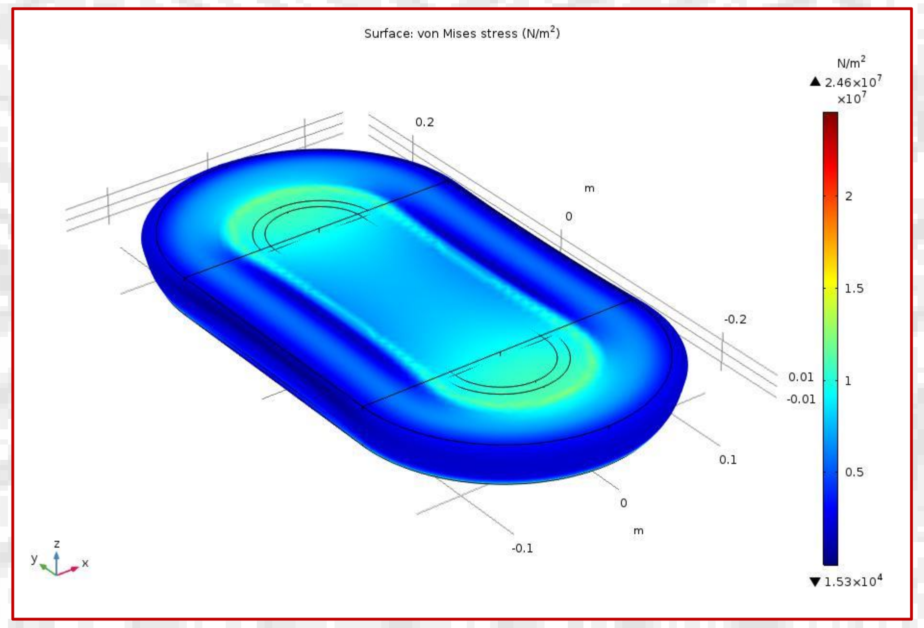


Mechanical modeling

Non insulated tape

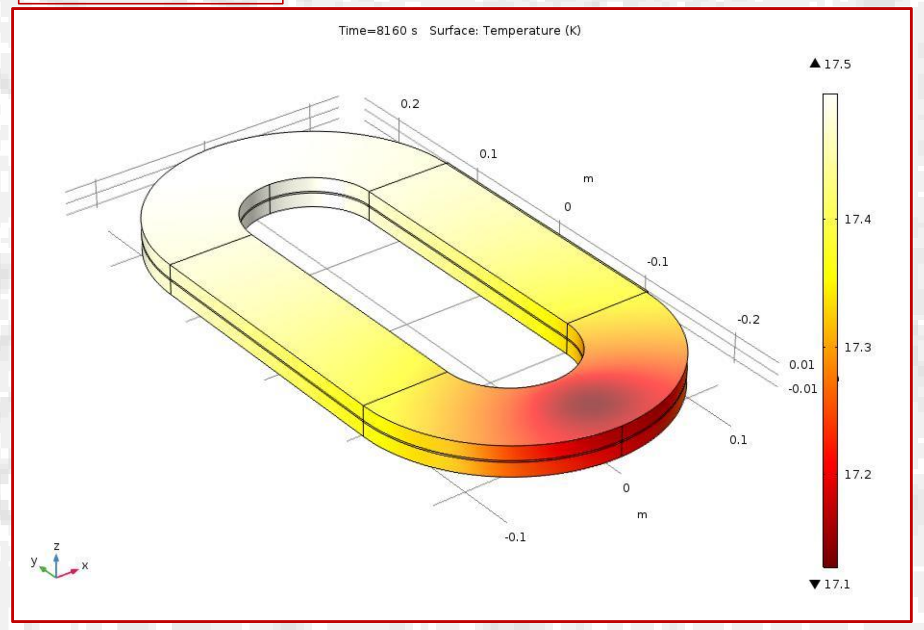


Kapton insulated tape

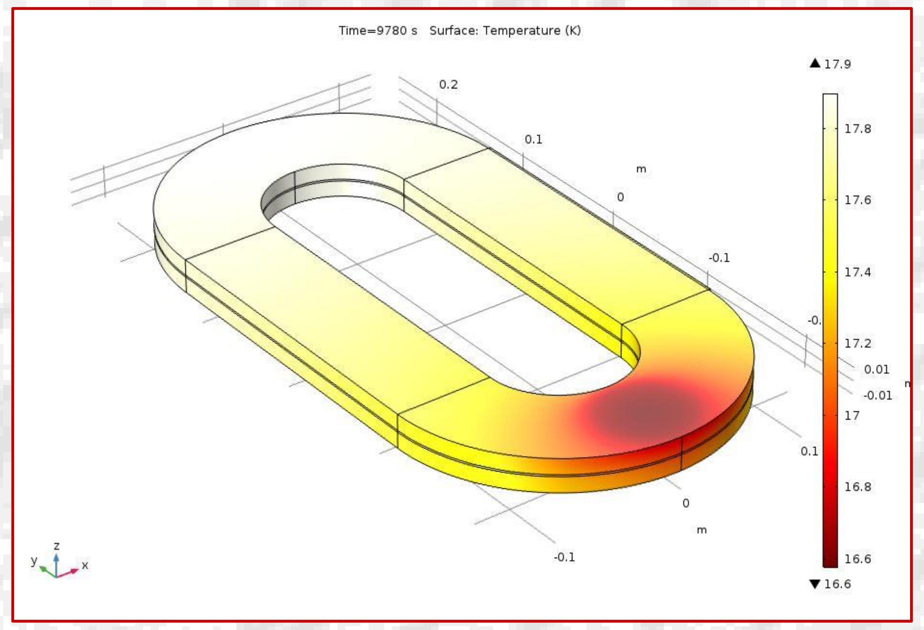


Thermal modeling

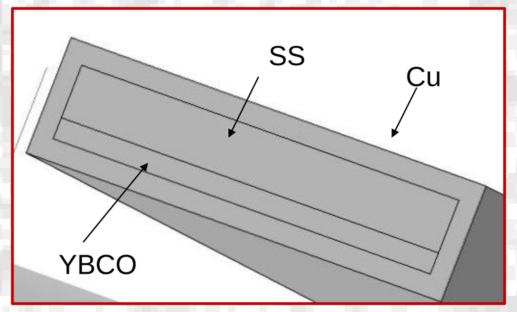
Non insulated tape

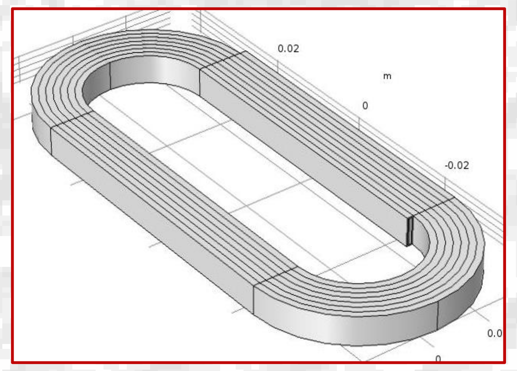


Kapton insulated tape



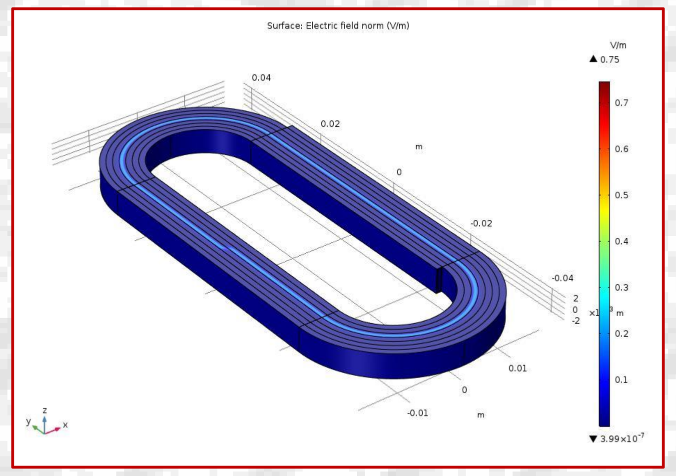
Current sharing

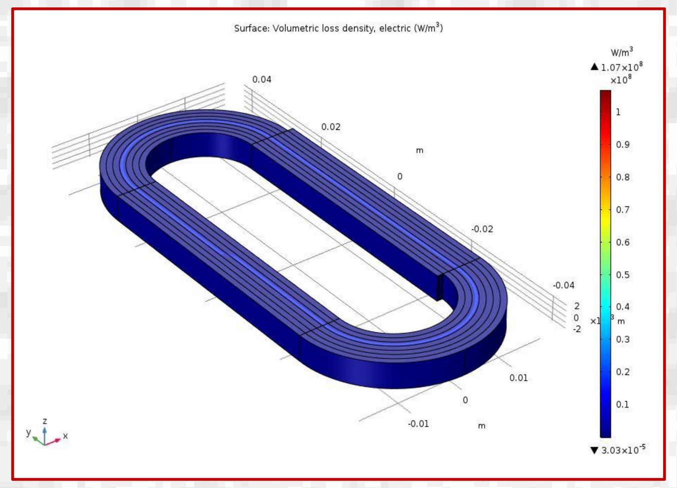


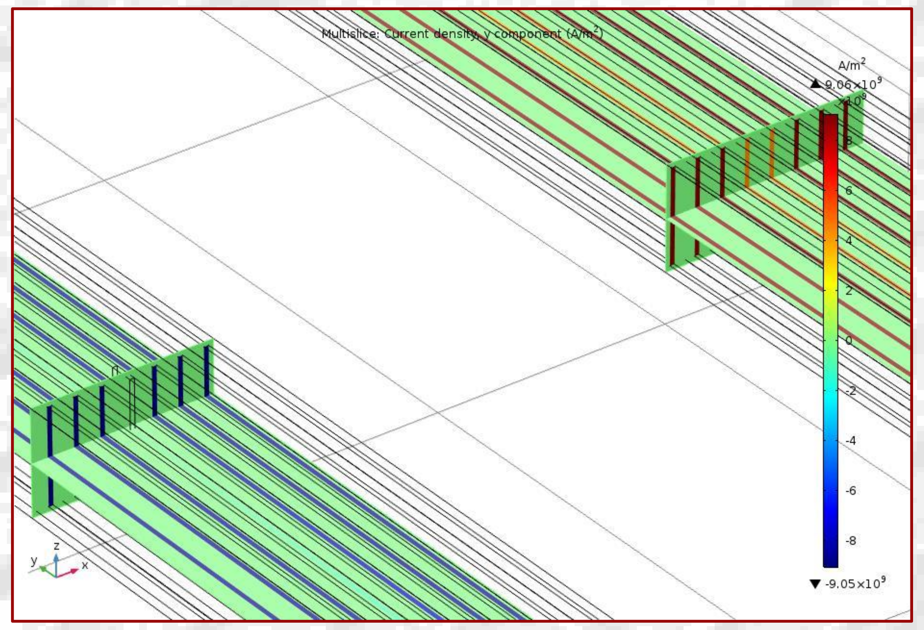


Maximum volumetric loss density = 2.5×10^8 W/m³

Non insulated tape

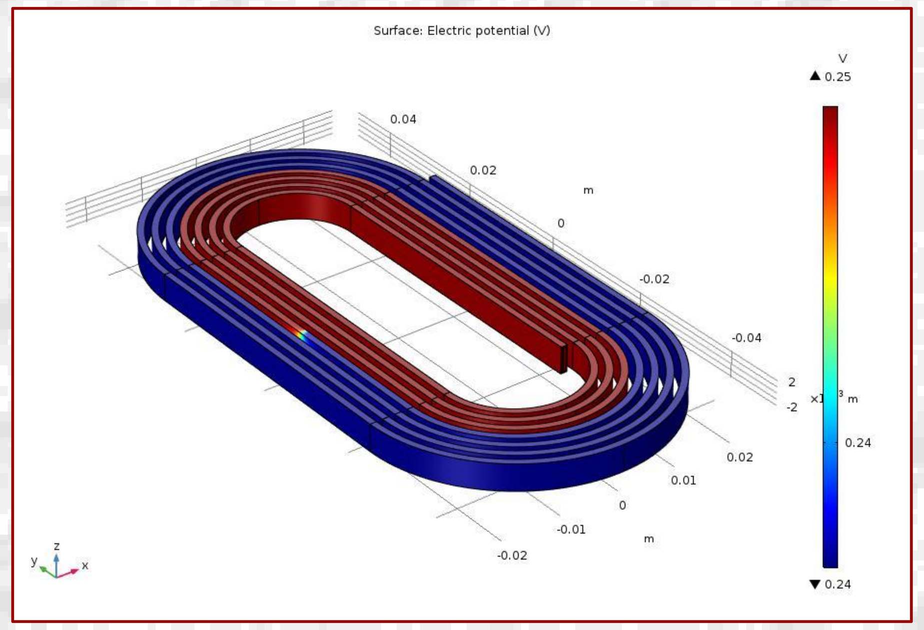


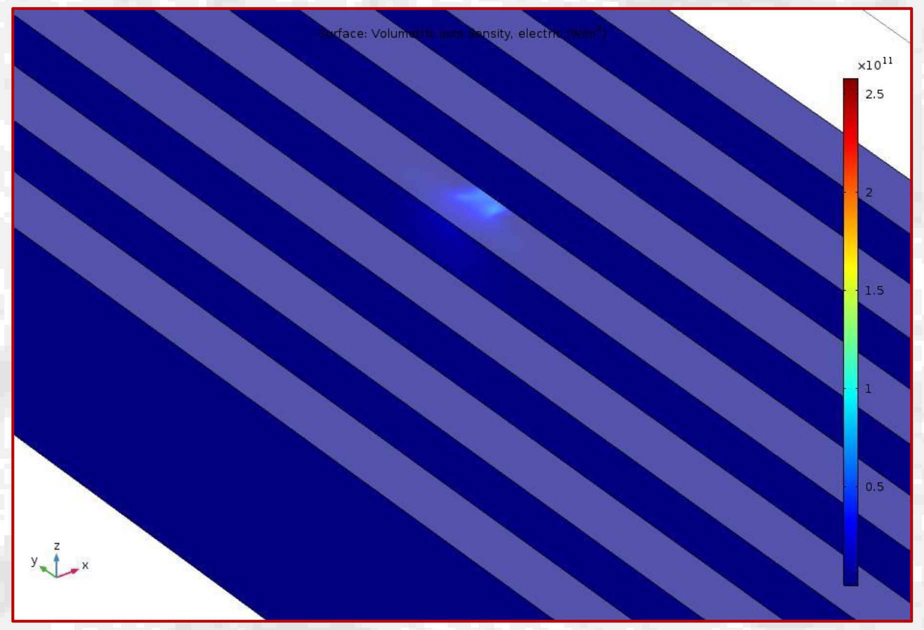




Current sharing around defect. $J_{c\ defect} = 0.1J_c$, transport current $I = 0.9I_c$.

Kapton insulated tape





Maximum volumetric loss density = 5.8×10^{11} W/m³

Summary

	Non insulated tape	Kapton insulated tape	Comment
Current to achieve max. field of 3 T on axis (A/turn)	381.2 (= $0.53I_c$)	474.57 (= $0.63I_c$)	
I_c (20 K) (A)	718.4	746	
Max. von Mises stress (MPa)	23.35	23.27	Critical stress ($0.9I_c$) = 600 MPa
Winding max. temperature (K)	17.5	17.9	
Winding min. temperature (K)	17.1	16.6	
Current sharing max. volumetric electric loss density (W/m³)	2.5×10^8	5.8×10^{11}	

Acknowledgments

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